Holocarpha macradenia Greene (Santa Cruz tarplant) Demography and Management Studies

prepared for:

State of California
Department of Fish and Game
Habitat Conservation Branch
1416 Ninth Street, 12th Floor
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Contract #P9930009

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May 2003

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I. Introduction. This project includes demographic monitoring; experimental germination and competition studies; and preliminary recovery tasks for *Holocarpha macradenia* Greene (Santa Cruz tarplant). This document is a report on progress since the beginning of this contract (2000). Several aspects of this project were already in progress but that earlier data is not reported in this document. Monitoring and experiments were conducted at the Porter Ranch (Monterey County), Arana Gulch (Santa Cruz County), and Wildcat Regional Park (Contra Costa County) populations. Work on material from the Twin Lakes State Parks (Santa Cruz County) population was conducted *in situ* at UC Berkeley.

Earlier work showed differences between populations in soil seed bank densities; the persistent soil seed bank is comprised of ray achenes; germination rates of disc and ray achenes differed in both the lab and the field conditions; litter suppresses germination. Ongoing studies include estimations of seed longevity, germination ecology, and soil seed bank depletion rates.

Deb Hillyard (CDFG), Department of Parks and Recreation-City of Santa Cruz, Tim Hyland and George Grey (CDPR), Don French (Watsonville Airport), Lauri Kiguchi (biologist), Kathy Lyons (biologist). Dan Salzar (TNC), Jane Holt and Mark Silberstien (Elkhorn Slough Foundation) provided access, invaluable advice, or assistance to the above work.

II. Porter Ranch: Demographic Monitoring and Population Census

IIA. Demographic monitoring at Porter Ranch. Demography of *Holocarpha macradenia* was monitored in 40cm x 45cm permanent plots at the Porter Ranch population in 1999-2000. Attempts were made to monitor in a grazed and ungrazed area but fences were not consistent throughout the year so only the grazed portion of the population was monitored.

In each area, 30 plot locations were randomly selected. Only plots containing *Holocarpha macradenia* were used for demographic monitoring. If the plot location did not contain *H. macradenia*, it was recorded but not used as a permanent plot. Some plots could not be relocated between data collection events and were replaced the following year with new plots.

Germination was monitored in the plots 1 to 2 weeks, 3 to 4 weeks, 6 to 8 weeks, and 10-12 weeks after the first saturating rain in late Fall or early winter. Germination was estimated by counting seedlings in each of the permanent plots. Survivorship of seedlings to seed set was monitored early spring and late summer. Germination patterns in plots with controlled seed input, and sizes of seedlings were used to insure counts accounted for mortality and new germination. Reproductive output was monitored in the field by counting the number of heads per plant on 250 plants. In addition, heads from 200 plants were collected outside the permanent plots. Fifty of those were randomly selected, and the number of disc and ray achenes per head counted. Germinating achenes, or excising embryos assessed viability.

Soil samples were collected in late summer, before seed dispersal, and in late winter/early spring, after germination. Soil samples were collected in plots along 10 meter transects between plots, and pooled into a single sample. Achene density was assessed by float and sieve methods.

Results. Results of demographic monitoring at Porter Ranch are shown in Table II-1. Rates of germination, reproductive output and soil seed bank densities, but not survivorship, were higher in 2001-2002 cohort than the 2000-2001 at this site. While the mean input of ray achenes was 72-129 achenes per plant, some plants produced over 120 heads, and estimated production of ray achenes for those plants was over 1800. In 2000, germination was lower in the ungrazed area than in the grazed area as would be expected.

Both pre-dispersal and post-dispersal soil seed bank were comprised of ray achenes. Germination was expected to be primarily disc achenes but also ray achenes. The growth rate of the soil seed bank was estimated using reproductive input, germination, survivorship, seed mortality, and seed bank density.

The rate of increase at Porter Ranch was 1.2 in 2000-2001, and 1.4 in 2001-2002. This is supported with an "observed" increase (estimated) from soil seed bank samples.

Table II-1. Results of Demographic Monitoring at Porter Ranch

Germination.

cohort (year)	germination (seedlings/0.18 sq. mtr)		frequency of plots with germination	
	grazed	not grazed	grazed	not grazed
2000 (2000-2001)	34.2	9.9	0.85	0.9
2001 (2001-2002)	39.3	n/a	recruitment in all existing plots	

Survivorship.

cohort (year)	survivorship to Spring		survivorship through seed set	
	grazed	not grazed	grazed	not grazed
2000 (2000-2001)	0.85	n/a	0.77	n/a
2001 (2001-2002)	0.69	.n/a	0.61	n/a

Reproductive output.

cohort (year)	viable disc achenes per plant		viable ray achenes per plant	
	grazed	not grazed	grazed	not grazed
2000 (2000-2001)	48.5	n/a	72.0	n/a
2001 (2001-2002)	52.8	n/a	129.0	n/a

Seed bank density.

cohort (year)	late summer (achenes/0.18 mtr)		spring (achenes/0.18 mtr))	
	grazed	not grazed	grazed	not grazed
2000 (2000-2001)	5502.1	n/a	6113.7	n/a
2001 (2001-2002)	6279.9	n/a	6576.8	n/a

IIB. Associated vegetation. Composition of vegetation in the demographic monitoring plots was estimated in the plots by visual estimated of cover using cover classes, by species, and by life history group (non-native annual grasses, native annual forbs, native perennial grasses, etc.).

Vegetation associated with *Holocarpha macradenia* is summarized by life history group in Table II-2. Associated vegetation in the grazed area is predominately native and non-native annual forbs, and non-native annual grasses. In summer, *Holocarpha* dominates. In the ungrazed area, associated vegetation was predominately non-native annual grasses in spring and summer.

Table II-2. Summary of Vegetation Associated with *Holocarpha macradenia* seedlings in mid-Spring at Porter Ranch: mean cover estimated from cover classes

	Spring 2001		Spring 2002	
	grazed	**not grazed**	**grazed**	**not grazed**
all vegetation	55.7	87.5	60.0	52.5
native perennial grass	12.5	2.5	9.4	0.0
non-native annual grass	14.3	67.5	5.6	42.5
native annual forb (except *Holocarpha*)	25.9	2.6	28.8	0.9
native perennial forb	2.5	0.0	0.0	0.0
non-native annual forb	44.2	0.8	6.5	1.9
non-native perennial forb	0.5	2.5	0.3	0.1
mulch	1.3	11.2	0.4	8.8
Holocarpha macradenia	13.42	4.2	35.0	18.5

IIC. Distribution and abundance. The distribution and abundance (from visual estimates of low, medium and high density) of reproductive plants on the Porter Ranch were mapped from permanent baselines in summer 2000 and 2001. Low abundance was considered 5 plants or less per square meter, while high abundance is essentially 100% cover in a square meter. However, because this is subjective, this assessment of abundance indicates the relative density of plants at the site within for that year and not between years.

On the east side of the creek, all reproductive plants were counted in 1 meter wide belts, and an average and the population areas was used to estimate population size. On the west side of the creek and elsewhere in the population, individual plants were counted. Population size was estimated to be 45625 in summer 2001, and 43,413 in 2002.

III. Watsonville Airport: Demographic monitoring, Effects of Mowing, and Effects of Non-Native Annual Grasses

IIIA. Demographic monitoring. Demography of *Holocarpha macradenia* was monitored in 40cm x 45cm permanent plots in each of five areas in 1999-2000. Two of these areas were grazed (Temporary Easement-A/Temporary Easement-A1, Temporary Easement-C[1]), two were mowed (Temporary Easement-A/ Temporary Easement-A1, Permanent Easement 14), and two were unmowed (Permanent Easement 14, Permanent Easement 12). However, difficulties occurred with mowed and unmowed treatments. One of the mowed sites was plowed, destroying plots and plants, and the unmowed sites were mowed in 2000 and 2001. As a result, plot areas included two mowed areas, and two grazed areas. Accessible, unmowed areas with sufficient *Holocarpha macradenia* are not common at the site.

In each area, 15-20 plot locations were randomly selected. Only plots containing *Holocarpha macradenia* were used for demographic monitoring. If the plot location did not contain *H. macradenia*, it was recorded but not used as a permanent plot. Some plots could not be relocated between data collection events and were replaced the following year with new plots.

Germination was monitored in the plots 1 to 2 weeks, 3 to 4 weeks, 6 to 8 weeks, and 10-12 weeks then February after the first saturating rain in late Fall or early winter. Germination was estimated by counting seedlings in each of the permanent plots. Survivorship of seedlings to seed set was monitored early spring and late summer. Germination patterns in plots with controlled seed input, and sizes of seedlings were used to insure counts accounted for mortality and new germination.

Germination was monitored in the plots 1 to 2 weeks, 3 to 4 weeks, 6 to 8 weeks, and 10-12 weeks after the first saturating rain in late Fall or early winter. Germination was estimated by counting seedlings in each of the permanent plots. Survivorship of seedlings to seed set was monitored early spring and late summer. Reproductive output was monitored in the field by counting the number of heads per plant on 200 plants. In addition, heads from 200 plants were collected outside the permanent plots. Fifty of those were randomly selected, and the number of disc and ray achenes per head counted. Germinating achenes, or excising embryos assessed viability.

Soil samples were collected in late summer, before seed dispersal, and in late winter/early spring, after germination. Soil samples were collected along 10 meter transects between plots, and pooled into a single sample. Achene density was assessed by float and sieve methods.

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[1] Easements refereed to here are from the map of "Easements and Proposed Taxiway & Runway Expansion Watsonville Municipal Airport" prepared by the City of Watsonville, GIS Department, July 2000. Easements on subsequent versions may not correspond with this version.

Results. Results of demographic monitoring at Watsonville Airport are shown in Table III-1. Germination is higher in mowed areas, than grazed areas but survivorship and reproductive output rates are lower. Reproductive output is 6.0 to 6.2 achenes per plant in mowed areas, and 32.0 to 41.9 in grazed areas.

As with Porter Ranch and other *Holocarpha macradenia* soil seed bank samples, both pre-dispersal and post-dispersal soil seed bank were comprised of ray achenes. Germination was expected to be primarily disc achenes but also ray achenes. Soil seed bank density is lower in the grazed area but this may be due to the patchiness of the population, and the collection pattern of the soil samples. These patterns are consistent between the two cohorts. The effects of historic scraping without experiments controlling management can not be separated from mowing treatments, these differences between the two management types therefore should be thought of as mowing in scraped habitat, and grazing in unscraped habitat.

Table III-1. Results of Demographic Monitoring at Watsonville Airport

Germination.

cohort (year)	germination (seedlings/0.18 sq. mtr)		frequency of plots with germination	
management	mow	graze	mow	graze
2000 (2000-2001)	66.2	30.8	0.79	0.12
2001 (2001-2002)	78.3	49.4	recruitment in all existing plots	

Survivorship.

cohort (year)	survivorship to Spring		survivorship through seed set	
management	mow	graze	mow	graze
2000 (2000-2001)	0.84	0.46	0.42	0.39
2001 (2001-2002)	0.72	0.81	0.35	0.71

Reproductive output.

cohort (year)	viable disc achenes per plant		viable ray achenes per plant	
management	mow	graze	mow	graze
2000 (2000-2001)	0.6	9.5	4.9	22.5
2001 (2001-2002)	0.7	11.8	5.0	29.9

Seed bank density.

cohort (year)	late summer (achenes/0.18 mtr)		spring (achenes/0.18 mtr))	
management	mow	graze	mow	graze
2000 (2000-2001)	108.1	41.9	122.1	49.4
2001 (2001-2002)	88.2	34.0	146.8	28.1

IIIB. Associated vegetation. Composition of vegetation in the demographic monitoring plots was estimated in the plots by visual estimated of cover using cover classes, by species, and by life history group (non-native annual grasses, native annual forbs, native perennial grasses, etc.).

Vegetation associated with *Holocarpha macradenia* is summarized by life history group in Table III-2. Associated vegetation in the mow areas is predominately native annual forbs and *Holocarpha* and some native perennial grass (*Danthonia californica*). In summer, *Holocarpha* dominates. In contrast, in the grazed areas, associated vegetation is predominately non-native annual grasses in spring and summer. If including *Holocarpha*, overall vegetation cover does not differ between the two management types.

Table III-2. Summary of Vegetation Associated with *Holocarpha macradenia* seedlings in mid-Spring at Watsonville Airport: mean cover estimated from cover classes

cohort (year)	2000 (2000-2001)		2001 (2001-2002)	
	mow	**graze**	**mow**	**graze**
all vegetation	60.0	67.5	60.0	52.5
native perennial grass	10.0	0.0	9.4	0.0
non-native annual grass	4.3	67.5	5.6	42.5
native annual forb (except *Holocarpha*)	37.8	2.6	38.8	0.9
native perennial forb	0.0	0.0	0.0	0.0
non-native annual forb	8.1	0.8	6.5	1.9
non-native perennial forb	0.65	0.1	0.3	0.1
mulch	0.5	4.8	0.4	8.8
Holocarpha macradenia	30.8	17.0	35.0	18.5

IIIC. Effects of Mowing. Observations and initial data suggest that seed bank density, and reproductive rate of *Holocarpha macradenia* at the Watsonville Airport is lower than at most other sites. This may increase population vulnerability despite the overall large size of the population. One or more factors may contribute to variation in demography between sites including differences in vegetation management, genetics, or physical attributes of the habitat (either natural or anthropogenic). As a start in understanding demography of the Watsonville Airport population, an experiment to investigate the effects of management (mowing) was established. Several possible effects of mowing were considered including reduced seed input (direct impact to *H. macradenia*), reduction in associated plant cover, and reduction in soil nutrients.

Two areas were established to exclude regular mowing activities and conduct controlled clipping experiments (Permanent Easement 14, Permanent Easement 16). In these plots, one of the following four treatments were applied in April after seedlings were counted (10 replicates each per area): only *Holocarpha* plants were clipped, associated vegetation was clipped and removed, associated vegetation was clipped and left in the plot, or all vegetation including *Holocarpha* was clipped and removed. Both of the designated areas were inadvertently mowed in 2001 and 2002 after treatment. These plots were abandoned because the treatments were no longer valid.

IIID. Field Competition Studies. The purpose of this experiment was to better understand the effects of annual grasses on *H. macradenia* seedlings and reproductive output. Previous work suggests that annual grasses and other vegetation prevent recruitment but it is unclear if annual grasses also limit seedling survivorship and reproductive output. Understanding the effects of competition on various life history stages, and the effects of rooted vegetation versus litter is important to understanding of different management regimes most beneficial to *H. macradenia*. In relation to mowing it is useful to know if removal of biomass is important.

In Temporary Easement B, strips of garden trimming approximately one meter long and two decimeters tall were installed in the soil as 30 cm diameter circular plots. The trimming was pounded into the ground so that the top was flush with the soil surface. The purpose of the trimming was to insure that plants inside the plots were only affected by the roots of other plants inside the plots. In January 2001, thirty seedlings of *H. macradenia* were planted in each circular plot in two concentric rings (the inner with 6 seedlings, the outer with 24). One of the following treatments was applied to the plots: removal of all vegetation except the *Holocarpha* seedlings and placement of 10-15 grams of grass litter in the plot, and no a treatment control (i.e. associated vegetation remains rooted). Plots were checked monthly for seedling survivorship, and to keep litter and no vegetation treatments intact. In the first two months, survivorship in control plots was slightly but not significantly lower than the litter and vegetation removal plots. The site was disturbed before the plants were mature.

IV. Arana Gulch Population: Effects of management treatments on *Holocarpha macradenia* and associated vegetation.

Arana Gulch is one of the largest remaining natural populations of *Holocarpha macradenia*. Four colonies or patches of *H. macradenia* (referred to as colonies A-D) have been recorded at the site. Grazing occurred at Arana Gulch up until approximately 1989. Prior to cessation of grazing, estimated population sizes of *Holocarpha macradenia* were on the order of 100,000. After removal of cattle, the tarplant population declined, and then disappeared. Between 1995 and 1998, early summer scraping, mowing and fall burning were used as means to recover the population by reducing competition from non-native plants. An arson fire in Fall of 1996, that included the large colony A, yielded the highest density of *Holocarpha macradenia* plants at the site for that year (Lyons, pers. comm.). In October 1998, a prescribed burn was conducted within colony B but no seedlings were observed in that area as late as June 1999 (pers. obs.). Post-fire soil samples taken in that area contained viable achenes of *H. macradenia* were found in those samples (pers. obs.). That suggests that the fire did not stimulate germination from the soil seed bank but does not exclude the possibility that the fire stimulated germination but the seedlings did not survive.

Recruitment in the largest colony (A) declined sharply in the fall 1999-summer 2000 cohort. In 1998, population size in colony A was over ten thousand individuals but during 1999-2001 the population decline sharply, and was almost entirely restricted to the scraped area. In 1999, the population consisted of approximately 1228 individuals, 1053 in 2000, and 619 in 2001. Recruitment in the second largest colony (B) last occurred in fall of 1997. Recruitment has not occurred in the two small colonies (C and D) for several years.

The 1995-1998 treatments showed that mechanical scraping, and raking and hoeing yielded more plants per acre than other treatments applied to colony A. These treatments were applied in single large blocks so results may reflect spatial differences in seed bank density rather than the relative effectiveness of each treatment. Mowing in colony A in June of 1999 had almost no effect on recruitment (<10 plants in mow areas). Recruitment rates after burning range from none (1998) to high (1996).

In Spring of 2000, an experiment was established at Arana Gulch, and data were collected to test the effects of mowing, burning and scraping, and the timing of their application on *H. macradenia*, and associated vegetation. None of the treatments occurred in 2000. Data was collected again in 2001, and treatments followed that year. Post-treatment data were collected 2001 to present (Only 2001-2002 results presented here).

Methods. Five 20 by 50 meter blocks were established for experimental management treatments. Three are in Santa Cruz tarplant colony A, one in colony B. The fifth is just north of colony A. Each block is comprised of 10 plots each, 10 by 10 meter in size. A permanent 3 by 3 meter subplot in each plot was used to monitor vegetation cover and composition, and *Holocarpha* demography. Pre-treatment sampling in each subplot included estimation of the following: composition, height and cover of vegetation; standing and residual biomass; and density of *Holocarpha* seedlings. Biomass sampling occurred outside the subplot in the remainder of the plot.

Pre-treatment sampling occurred in late April to early May 2000 but none of the management treatments occurred, so the sampling occurred again in 2001. The first year post-treatment sampling occurred in October 2001 through September 2002.

Cover and composition of vegetation in late Spring was estimated using two methods. The first accounted for all species in the 3 by 3 meter subplots by estimating the cover using 7 cover classes. The second estimated cover along four parallel, evenly spaced, 3-meter transects within the subplot using point-intercept method. Twenty-five points along each transect were sampled using a frame. While the cover estimates were comprehensive for all species in the plots, the estimates using point-intercept was more accurate and reliably repeated. Each plot was checked for *Holocarpha* seedlings.

The ten management treatments, including a control (no treatment), were randomly assigned to each of the ten plots. They were selected to test the effect of management type (mowing, burning, scraping), and timing of management (spring, summer, fall). However, the fall treatments did not occur. Mowing occurred May 24-25 and August 2; scraping occurred on June 6 and August 7; and burning occurred on June 19 and October 18, 2001. The "spring" burn occurred after seed dispersal of the dominant annual grass (*Vulpia bromoides*) but would have ideally occurred before dispersal. Vegetation remaining after mowing was more than optimal (averaging 2 decimeters tall).

Post-treatment sampling included estimates of cover in late fall following the last treatment, seedling density in late 2001. In Spring 2002, estimates of vegetation cover and composition, and seedling density, and survivorship were made. In addition, soil cores were taken from along the four transects within the sub plots, and were used to determine density of the dormant seed bank in each plot. Late in the year reproductive output in the plots was also estimated.

Results. Scraping resulted in the highest recruitment density of *Holocarpha macradenia*, and other native annual forbs (Table IV-1). Mean recruitment of *Holocarph*a in the scrape plots was much higher than the burn plots, and none occurred in the mow or control plots. The differences between burn and scrape treatments was significant ($p<0.05$), but not for burn versus mow or control, and mow versus control. Treatment was more important than timing but explained but only 18% of the variability in *Holocarpha macradenia* density. Regression of seed bank density and recruitment showed no significant correlation suggesting a treatment effect rather than a seed bank effect. Post-treatment (fall) thatch cover was significant in determining *Holocarpha* recruitment. Survivorship was not significantly different between scrape and burn plots.

Table IV-1. 2002 density (plants per square meter) and percent cover of *Holocarpha macradenia* in all blocks (n=5), and only in blocks plots with known *Holocarpha macradenia* seedbank (n=4).

	control	**scrape**	**mow**	**burn**
mean density (n=5)	0.0	20.5	0.0	0.7
mean density (n=4)	0.0	26.2	0.0	0.8
mean cover (n=5)	0.0	12.5	0.0	0.4
mean cover (n=4)	0.0	15.6	0.0	0.5

Pre-treatment sampling showed no significant difference in cover of total vegetation, bareground, litter, non-native grasses, non-native forbs, or native forbs (see Table IV-2 for mean pre-treatment abundance's). Native annual forbs were absent in pre-treatment plots. Scraping also resulted in the greatest cover and diversity of native annual forbs and gramnoids. *Lupinus nanus* dominated some of the scrape plots. Native annual forbs and gramnoids not found in pre-treatment monitoring but occurring in scraped plots but at low cover include: *Plagiobothyrs undulatus*, *Trifolium barbigerum* var. *barbigerum*, *Juncus bufonius*, *Scirpus kolieopis, Cicendia quadrangularis*, *Centunculus minimus*, and *Deinandra corymbosa*. Richness of native species was significantly higher in late scrape plots than control and early burn. The increase in native species richness in late scrape plots was significantly higher than in control and late mow plots. Cover of the only native perennial forb, *Camissonia ovata*, and the native perennial gramnoids decreased but were not significantly effected by the treatments. Although decreases of gramnoids did occur in the scrape plots, some regeneration occurred from underground shots. In addition, fire was expected to reduce the cover of *Danthonia californica* but did not have a significant effect. This lack of fire effect may also be in part due to the mildness of the burns.

Both cover estimates and point-intercept methods showed that bareground, mulch and non-native annual grasses were significantly effected by treatments. Early scraping resulted in significantly higher increase in spring bareground than the control, late burn and both mow treatments. Mulch reduction was higher in both early and late scrape plots than all other treatments but they were not significantly different from each other. Early burning resulted in a significant higher mulch reduction than early mowing and the control plots. Non-native annual grasses were significantly reduced in both scrape treatments when compared to control or mowed plots. Although dramatic increases in forb cover occurred in scraped plots within Macroplots 1-3, changes were not significant due to a high amount of variance when including Macroplots 4 and 5.

Table IV-2. Vegetation composition in pre-treatment (2001), and treated plots (2002) at Arana Gulch: mean cover estimated from cover classes

treatment/ year	pre-treatment /2001	control/2002	burn/2002	mow/2002	scrape 2002
all vegetation	87.5				
litter	87.5	67.9	49.7	0.85	0.2
bareground	0.6	2.3	4.1	0.75	10.65
native perennial gramnoids	9.6	10.3	9.9	9.9	1.0
native annual forbs	0.0	1.2	3.2	0.0	23.6
native perennial forbs	0.1	0.2	0.2	0.0	0.3
non-native grasses	87.5	73.1	48.4	82.5	38.0
non-native perennial forbs	3.0	2.1	3.2	2.5	3.8
non-native annual forbs	32.1	30.0	48.2	34.0	54.8

V. Twin Lakes State Park: Increase seed stock for outplanting.

The two main objectives of work done with the Twin Lakes State Park population were to increase seed stock for restoration efforts, and assess the number of breeding types. Material from the win Lakes State Park *Holocarpha macradenia* population was propagated in order to increase seed stock for outplanting; and maximize diversity of breeding types through controlled pollination. Later germination and viability testing will of these crosses may provide information on the number of breeding types represented in this seed stock. That testing will occur when seeds are germinated for outplanting.

This population is very small and limited amount of material and potentially genetic diversity is available. Material was individually artificially germinated to reduce losses. Seeds from cohorts and individuals in that cohort were kept separate and tracked. Fifty-three of the achenes from the 1998-1999 natural (field population) cohort, and the 1998-1999 captive grown from the 1997-1998 natural cohort were grown in growth chamber and greenhouse conditions during summer 2000. Forty-four individuals survived to flowering, and were used for controlled pollination. Most losses were in the embryo stage and attributed to low vigor as indicated in a curled radical.

Percent viability of each cohort was estimated while germinating fruit for propagation. The estimated percent viability of captive grown fruit (1998-1999) was less than estimated viability of natural fruit. The percent viability of the natural population was less than larger natural populations. However, a large proportion of disc fruits were used to estimate the percent viability of the Twin Lakes cohorts, and the actual percent viability may be higher when the remainder of the ray fruit is included.

Crosses between these plants were designed to maximize outcrossing between individuals or heads depending on available information regarding original seed stock. In some cases, heads from a given cohort were available but the relatedness between the heads (i.e. which individual in the population they came from) was not known because the heads were removed from the plants and combined. In that case, crosses within that cohort may not be successful. Most of those plants were crossed with plants from other cohorts. For most fruit in a cohort, the plant and head on the plant it came from was known and crosses were made between as many other plants as possible. In addition, heads were also crossed with plants from Arana Gulch, Watsonville Airport, Porter Ranch and Wildcat Regional Park (transplanted Pinole and Richmond populations) to determine relatedness. Assessment of fruit viability, and therefore diversity of S-alleles is not completed for this first set of crosses. Success of theses crosses will be evaluated when the resulting fruits are propagated for outplanting.

Table V-1. Twin Lakes State Park *Holocarpha macradenia* population: *in situ* seed stocks based on viability estimates

Seed source/cohort	Number of fruit from cohort	Estimated number of viable fruit	Outplanted 2000-2001	Estimated viable achenes available
1997-1998 field/captive grown[1]	395	174	24	174
1998-1999 field	78	57	29	28
1999-2000 field	325	237[2]	0	238
Estimated yield 2000 multi-cohort captive\crosses	2,700	1188[3]	0	1113
Total	**3,498**	**1,656**	**53**	**1603**

[1] Captive grown by State Parks in 1998-1999 from the 1997-1998 field cohort.

[2] Based on 73% viability of 1999-2000 field cohort.

[3] Based on 44% viability of 1998-1999 captive cohort. Actual viability expected to be different due to hand pollination versus natural pollination.

Also, fruit from one-third of fruit from the 1999-2000 natural population was collected September though October 2000, and one-third of fruit from the 2000-2001 natural population was collected as plants matured. Fruits are collected from heads ready to shatter and disperse. Material is stored separately by individual plant and by head.

In 2001, fifty of the plants resulting from the 2000 multi-cohort captive plants were propagated for trial outplanting. Of these, 18 were planted outplanted at Twin Lakes State Park in January 2002. Survivorship and reproductive output of these individuals is being tracked by Tim Hyland. A more extensive population recovery is being planned for this population.

VI. Wildcat Regional Park Demographic Monitoring

East Bay Regional Parks stand #6 (CNDDB Occurrence #30) in Wildcat Regional Park is the largest introduced population in Alameda or Contra Costa county single year of demographic data was collected at for the 2000-2001 cohort. Plants were monitored with 40 randomly placed, and temporary 40 cm by 45 cm plots. Only plots containing *Holocarpha macradenia* were used for demographic monitoring. If the plot location did not contain *H. macradenia*, it was recorded but not used as a permanent plot.

Germination was monitored in the plots 1 to 2 weeks, 3 to 4 weeks, 6 to 8 weeks, and 10-12 weeks then February after the first saturating rain in late Fall or early winter. Germination was estimated by counting seedlings in each of the permanent plots. Survivorship of seedlings to seed set was monitored early spring and late summer. Germination patterns in plots with controlled seed input (in Santa Cruz County), and sizes of seedlings were used to insure counts accounted for mortality and new germination.

Germination was monitored in the plots 1 to 2 weeks, 3 to 4 weeks, 6 to 8 weeks, and 10-12 weeks after the first saturating rain in late Fall or early winter. Germination was estimated by counting seedlings in each of the temporary plots. Survivorship of seedlings to seed set was monitored early spring and late summer. Reproductive output was monitored in the field by counting the number of heads per plant on 200 plants. In addition, heads from 200 plants were collected outside the permanent plots. Fifty of those were randomly selected, and the number of disc and ray achenes per head counted. Germinating achenes, or excising embryos assessed viability.

Soil samples were collected in late summer, before seed dispersal, and in late winter/early spring, after germination. Soil samples were collected along 15 meter transects between plots, and pooled into a single sample. Achene density was assessed by float and sieve methods.

Results. Results of demographic monitoring during 2000-2001 at Wildcat Regional Park are shown in Table VI-1. Reproductive rate is low because the mean number of heads per plant was 1.1. Observations in 2002 suggest head production per plant was higher than in 2001. The rate of seed bank growth is high (Ro=8.1) in part because the density is low rather than high rates of survivorship or fecundity.

Table VI-1. Results of Demographic Monitoring at Wildcat Regional Park, 2000-2001 cohort.

Germination.

	germination (seedlings/0.18 sq. mtr)	frequency of plots with germination
	42.2	0.96

Survivorship.

	survivorship to Spring	survivorship through seed set
	0.86	0.62

Reproductive output.

	viable disc achenes per plant	viable ray achenes per plant
	2.8	6.8

Seed bank density.

	late summer (achenes/0.18 mtr)	spring (achenes/0.18 mtr))
	26.8	32.2

VII. Conclusions and Recommendations.

1. One way of measuring population growth is size of the persistent soil seed bank. For *Holocarpha macradenia*, initial estimates of seed bank growth rate based on calculations of seed input and germination. of suggest mostly increasing populations for grazing and mowing (R_o=0.64-8.2). Estimates of soil seed bank density from soil samples support these increases. However, these results do not reflect the estimated density of the soil seed bank. This is especially true at Watsonville Airport for grazed and mowed sites where the density of the soil seed bank is lower than at other large populations but the growth rates is as high or higher than populations with large soil seed banks. Soil seed bank decay rates, predation rates, high rates of germination from the persistent soil seed bank, and effects of dispersal may attribute to this anomaly. Those factors and variation in demographic parameters will be used to resolve this question. Also more study is needed to determine if reproductive rate and soil seed bank density at Watsonville Airport is due to mowing regime alone.

Site	Management Type	Calculated mean Ro	Observed change in density 2000-2001	Seed bank density 2002 (#/0.18 sq. m)
Porter Ranch	grazing	1.3	1.1	6279.9
Watsonville Airport	mowing	1.0	1.2	88.2
Watsonville Airport	grazing	5.8	2.5	34.0
Wildcat Canyon	grazing	8.1	n/a	26.8

2. Experiments at Arana Gulch show that scraping is more effective than mowing or burning for stimulating recruitment of *Holocarpha macradenia* from the soil seed bank. Scraping was also most effective in increasing cover and richness of other native species. These results may last longer than burning and mowing. However, more information is needed on the potential negative effects of repeated scraping before scraping alone can be relied upon as method for managing *H. macradenia*. In addition, these treatments should be repeated in unaffected plots in order to determine if climate or more effective mowing and burning influence results. And, mowing and or grazing should be tested as a means to sustain the effects of scraping.

It should be noted that both the early and late fire were not adequate to remove thatch layer in the plots. Fire should not be eliminated as a possible restoration technique for *H. macradenia* until fires hot enough to consume all fuel in the plots have been tested. Both prescribed burns (1998 and 2001) were not effective but the accidental fire in 1996 was apparently very successful. Earlier or hotter burning may result in better removal of biomass and better *H. macradenia* recruitment.

3. Viable seed material of the Twin Lakes State Park population is currently sufficient to start a recovery effort of that population by outplanting seedlings. Plantings should maximize genetic

diversity by including seeds from all the cohorts and as many individuals as possible. Never should more than half the seed stock be outplanted at a time. After several years of successful outplanting, and deposition of achenes into the soil seed bank, a major disturbance (e.g. scraping, or burning) should be applied to stimulate germination, maximize outcrossing, and increase the soil seed bank.

4. The Wildcat Regional Park population #6 is probably large enough that seed could be used to augment existing smaller populations. Five percent of the reproductive output for the roughly 900 square meter population would be about 12,549 achenes.